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MECHANISMS OF INTERSPECIFIC INCOMPATIBILITY IN TUBER-BEARING *SOLANUM* SPECIES[1]

Leo A. Dionne[2]

Many potentially valuable *Solanum* species have not been used in potato breeding programs because of their marked incompatibility with *Solanum tuberosum* and its close relatives. Differences in ploidy complicate the use of some species but this can usually be circumvented. The major impediment to the use of several wild species has been that of cross-incompatibility which prevents the formation of viable hybrid seeds. A study to determine why seeds are not produced following interspecific cross-pollinations was undertaken at the Department of Agriculture Research Station in Fredericton with the ultimate objective of overcoming the various mechanisms that serve to isolate the tuber-bearing *Solanum* species from each other. The object of this paper is to report on the mechanisms preventing seed formation that were found in the course of this investigation.

Materials and Methods

Solanum species in the series *Acaulia*, *Bulbocastana*, *Cardiophylla*, *Circaefolia*, *Conicibaccata*, *Commersoniana*, *Longipedicellata*, *Polyadenia*, and *Trifida* were intercrossed in various combinations and with species of *Tuberosa*. When seeds were not produced after repeated intercrossing, attempts were made to determine the cause.

Interspecific crosses that repeatedly failed to produce seeds were investigated as follows: The unsuccessful crosses were repeated using three or more clones of each species as female parents. The exceptions to the number of clones used were *S. capsicibaccatum* and *S. yungasense*. When this work was undertaken only two clones of *S. capsicibaccatum* and one of *S. yungasense* were available. Pollinations were made from bulked pollen collected from three to twelve clones. A basic requirement for fertilization is that the pollen tubes reach the ovules. Seventy-two hours after pollination, three to six styles were collected from each female parent and examined for extent of pollen tube growth in the styles by the method of Dionne and Spicer (3). By an adaption of this method it was also possible to determine if pollen tubes had penetrated the placental tissues and entered the micropyles. This was accomplished by removing two opposite faces of the ovary with a thin longitudinal slice of ovary attached to the style. Fixation, hydrolysis, dissection and staining were done as originally described.

Unsuccessful crosses that showed the pollen tubes reaching the placental tissues of the ovary were examined for embryo development at three, ten and twenty days after pollination. These observations were made from paraffin sections of ovaries that were stained by several standard procedures. Three to six ovaries of each combination of parents were used to determine the extent of embryo development.

[1] Accepted for publication September 1, 1960. Contribution No. 33, Research Station, Canada Department of Agriculture, Fredericton, New Brunswick.

[2] Potato Breeding Section. The technical assistance of Mrs. William Hodgson (P. B. Spicer) in this investigation is gratefully acknowledged.

Results

In the crosses examined, failure to produce seeds was found to be due to three causes: (1) defective pollen tube growth and a consequent lack of fertilization, (2) the presence of too few fertilized ovules to stimulate the ovary into growth, (3) abortion of the embryos after fertilization.

Failure to produce seed was found to be due to inhibited pollen tube growth in the following 2n x 2n crosses.

S. agrimonifolium x *S. bulbocastanum* (and reciprocal)
S. agrimonifolium x *S. phureja* (and reciprocal)
S. bulbocastanum x *S. capsicibaccatum* (and reciprocal)
S. bulbocastanum x *S. chacoense* (and reciprocal)
S. bulbocastanum x *S. phureja* (and reciprocal)
S. chacoense x *S. jamesii*
S. chacoense x *S. pinnatisectum*
S. chacoense x *S. trifidum*
S. capsicibaccatum x *S. pinnatisectum*
S. phureja x *S. jamesii*
S. phureja x *S. pinnatisectum*
S. phureja x *S. trifidum*
S. phureja x *S. polyadenium* (and reciprocal)
S. polyadenium x *S. chacoense* (and reciprocal)
S. polyadenium x *S. phureja* (and reciprocal)

The 4n x 4n cross *S. tuberosum* x 4n *S. polyadenium* and its reciprocal as well as the 6n x 2n cross *S. demissum* x *S. polyadenium* and its reciprocal also failed to produce seed because of inhibited pollen tube growth and a consequent lack of fertilization.

Defective ovarian growth was found to be a second important mechanism that prevented the development of hybrid seeds.

In some of the crosses that gave no, or limited ovarian development a small number of pollen tubes reached the ovules and effected fertilization but this was rarely or never (depending on the cross) followed by ovarian development. In other crosses, an appreciable number of pollen tubes reached the ovules but development of the ovaries was inhibited When fertilization took place but seeds were not produced because of defective fruit development, seeds were usually obtainable by treating the ovary 24 hours after pollination with a drop of a 3-6 ppm solution of 2,4-dichlorophenoxyacetic acid or 25 ppm 2,4,5 trichlorophenoxyacetic acid (2). Seeds were also obtained from several of these crosses without auxin treatment by growing the plants out of doors in the autumn where parthenocarpic fruits were produced naturally. The lack of seed formation was found to be due to defective ovarian growth in the following crosses:

2n x 2n crosses

S. capsicibaccatum x *S. phureja**
S. capsicibaccatum x *S. chacoense**
S. phureja x *S. yungasense*

*In limited trials we were unable to induce fruit formation by 2,4-D or 2,4,5-T treatment in these crosses.

S. yungasense x *S. chacoense*
S. yungasense x *S. commersonii*
S. yungasense x *S. phureja*

2n x 4n crosses

S. chacoense x *S. stoloniferum*
S. phureja x *S. stoloniferum*

4n x 4n crosses

(*S. chacoense* x *S. demissum*) selfed (and sib-crossed)
S. stoloniferum x *S. tuberosum* (and reciprocal)

4n x 6n cross

S. tuberosum x *S. demissum*

Fertilization in the cross *S. tuberosum* x *S. stoloniferum* was observed only once. The reciprocal cross was somewhat better in this respect but only four viable seeds were obtained from several hundred pollinations.

A third impediment to seed formation was found to be early abortion of the hybrid embryos. In crosses that have this defect, pollen tubes reach the ovules and fertilization often takes place. Furthermore, a high percentage of the ovaries develop normally, but because of embryo abortion, viable seeds are never produced in most crosses and only occasionally in crosses involving *S. acaule*. The sequence of degeneration that occurs in this type of cross has been described by Beamish (1) and Lee and Cooper (6).

Embryo abortion was found to prevent seed development in the following:

2n x 2n crosses

S. jamesii x *S. chacoense*
S. jamesii x *S. phureja*
S. trifidum x *S. chacoense*
S. trifidum x *S. phureja*
S. pinnatisectum x *S. chacoense*
S. pinnatisectum x *S. phureja*
S. pinnatisectum x *S. capsicibaccatum*
S. pinnatisectum x *S. yungasense*

4n x 2n crosses

S. acaule x *S. bulbocastanum*
S. acaule x *S. cardiophyllum*
S. acaule x *S. pinnatisectum*
S. acaule x *S. trifidum*

The behaviour of *S. acaule* is unique among the South American species in that it accepts the pollen of species in the Mexican series *Bulbocastana*, *Cardiophylla*, *Pinnatisecta*, and *Trifida*. While there is extensive pollen tube inhibition when pollen from species in these series is used to pollinate *S. acaule*, in all crosses some pollen tubes reach the placental tissues and fertilization occurs. Furthermore, the resultant embryos occasionally reach an advanced state of development. In fact one authentic hybrid of *S. acaule* x *S. pinnatisectum* resulting from this work is now being grown. A similar hybrid has also been obtained by Dr. R. W.

Buck of the United States Department of Agriculture (personal communication).

Extensive embryo abortion was also found to occur in many other crosses, notably in crosses between species that have different levels of ploidy and those that have extensive but not total pollen tube inhibition. However, complete abortion of all embryos occurred only when species in the series *Pinnatisecta* and *Trifida* were used as female parents. In the reciprocals of these crosses all the pollen tubes were inhibited and consequently fertilization did not occur.

Discussion

Several more or less empirical methods for overcoming the cross incompatibility between *Solanum* species have appeared in the literature. Presumably the reported success of these methods is due to their value for eliminating the primary mechanism of incompatibility. Among the methods reported, induced polyploidy (4,7,8,9), grafting the female parent on tomato (5,8), stylar decapitation (10) and hormonal treatment of the ovaries have all been claimed to be effective.

The usefulness of induced polyploidy for overcoming the incompatibility between certain species has been confirmed at this laboratory. Treatment of the ovaries with 2,4-D or 2,4,5-T has also proved to be an effective method for producing seeds when defective fruit development is primarily responsible for a lack of seed formation. Grafting on tomato and the stylar decapitation technique were both tried extensively without success. Neither of these techniques was of any value in stimulating pollen tubes from incompatible crosses to reach the placental tissues of the ovaries. The results of our work with these techniques and others suggested in the course of these studies will be published in subsequent papers.

Several of our results confirm the findings of others who have reported on interspecific cross pollination of *Solanum* species. However, the cross *S. tuberosum* x 4n *S. polyadenium* is a notable exception. Two workers (8,10) have reported that hybrids of this cross were readily obtained. We were unable to duplicate these results. Although several hundred pollinations were made, viable seeds were not obtained. Moreover, examination of numerous *S. tuberosum* styles pollinated with pollen from five tetraploid clones of *S. polyadenium* failed to show any pollen tubes reaching the placental tissues of the ovary. If hybrids of this cross were actually obtained, the contradictory results must be attributable to differences in compatibility of *S. polyadenium* strains with *S. tuberosum*. It may be significant in this connection that the two strains of *S. polyadenium* used in this study were both self-incompatible. The strain used by Swaminathan (9) was reputedly completely self-compatible.

Summary

The failure to produce seeds following interspecific crosses of tuber-bearing species of *Solanum* was found to be due to three causes: (1) pollen tubes were inhibited in the style so fertilization was not effected; (2) fertilization took place but the ovary failed to develop; and (3) fertil-

ization was followed by complete abortion of all embryos at an early stage in their development.

Crosses in which the various mechanisms leading to a lack of seed formation that were encountered are listed in this paper.

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ERLI-RED, A NEW EARLY VARIETY OF POTATO WITH BRIGHT RED TUBER COLOR AND SUPERIOR MARKET ATTRACTIVENESS[1]

BEN PICHA[2]

Three years of experiment station trials, combined with commercial growing and marketing tests, indicate that selection 50.4-52-40 merits introduction as a new variety, and herewith is released as Erli-Red.

The important characteristics of Erli-Red are early maturity, the bright red color of the tubers, uniformity of size and market attractiveness. It is similar to Waseca in earliness and compares favorably in yield with varieties in this maturity class. Freedom from hollow-heart, knobs, growth cracks and internal defects make Erli-Red an ideal early market variety.

Erli-Red (Fig. 1) was tested in North Dakota, Minnesota and other states under the pedigree number 50.4-52-40 (later shortened to P 40). It was selected from a cross made in 1950 between two seedling selections, 43.17-16 as the pollen parent and 43.23-6 the seed parent. Both of these selections trace back to Early Ohio and 44537 (USDA) which is a sib of Sebago derived from Katahdin x Chippewa. The family line was grown in the year 1951 on the W. W. Turgeon farm at Oklee, Minnesota and the selection was made that year. Its number was assigned in 1952 after the second year of observation.

The Pedigree of Erli-Red is as follows:

			11-1-25
		15-2	X
			66-1
	43.17-16	X	
			S 44537
		528-170	X
			Richters Jubel
Erli-Red (50.4-52-40)	X		
			Katahdin
		S 44537	X
	43.23-6	X	Chippewa
		Early Ohio	

DESCRIPTION

PLANTS: Early maturing, medium, upright. *Stems*: medium thick, pubescent, angled. *Nodes*: thickened, pigmented. *Internodes*: medium length, slightly pigmented. *Stipules*: medium to small, pubescent, clasping. *Leaves*: large, medium green, closed, pubescent. *Terminal Leaflets*: ovate, medium large, asymmetrical, decurrent, seldom lobed. *Primary leaflets*: oblong ovate, medium large, asymmetrical, mostly paired to alternate, mean length[3] 83.3 mm ± .78 mm (3.2 inches), mean width 51.4 mm ±

[1] Accepted for publication September 10, 1960.
[2] Potato grower and breeder, Grand Forks, P.O. Box 816, N. D.
[3] Salaman, R. N. 1926. The leaf index, P 163-170. *In* R. N. Salaman, Potato varieties. Cambridge Univ. Press, London.

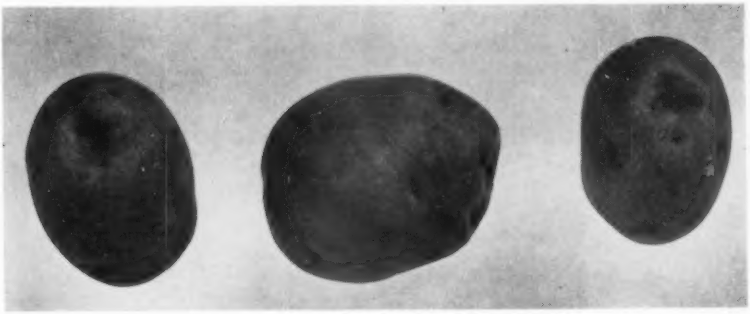

FIG. 1.—Tubers of Erli-Red variety.

.5 mm (2.02 inches). *Secondary leaflets*: many large prominent, petiolules occurring freely varying in size, pubescent. *Tertiary leaflets*: numerous, pubescent. *Midrib*: underside color green, upper side pigmented base of petioles' attachments, entire rib pubescent.

FLOWERS: *Buds*: violet. *Calyx lobes*: medium, pigmented purple at base, 3 to 5 mm in length, tips mostly straight, pointed. *Corolla*: violet, medium size mostly 30 mm, points reflexed, pubescent at points where pointed outward and inward. *Anthers*: large, orange, openings elliptic. *Pollen*: abundant, fertile. *Stigma*: mostly 3 mm above anthers, globose, 3-lobed.

TUBERS: Somewhat oblong, slightly flattened, medium thickness, mean length 78.47 mm ± .97 mm (3.09 inches), mean width 72.6 mm ± .71 mm (2.86 inches), mean thickness 62.9 mm ± .55 mm (2.48 inches). *Indices*: width to length 75.95 mm ± .2 mm, thickness to length 63.43 mm ± .25 mm thickness to width 66.94 mm ± .25 mm. *Skin*: generally smooth to slightly flaky, deep red in periderm, cortex white. *Eyes*: medium shallow, color same as skin, well distributed. *Flesh*: white. *Sprouts*: violet. *Maturity*: early (95 to 100 days). *Stolons*: short, easy detachment.

GENERAL CHARACTERISTICS: No particular claims have been established for resistance to disease. Erli-Red seems to have moderate scab resistance according to reports from commercial growers in various areas when grown beside other varieties, and usually is free from knobs, hollow heart, growth cracks and roughness or oversize.

Yields, when grown under irrigation, generally exceed the Waseca and Dazoc. Without irrigation it usually yields as much as Waseca, Dazoc or Triumph and tends to have more size B tubers (Table 1).

Tuber set of Erli-Red ranges from 5 or more tubers, under two-stem plants to 10 or more, under three- and four-stem plants. Its tubers develop on short stolons, are easily detached, resistant to abrasion, and are free from air checking.

Its specific gravity range and cooking quality are similar to those of the Triumph, Dazoc or Norland and vary with growing conditions. Palatibility of Erli-Red is excellent.

The storage ability of Erli-Red under Red River Valley conditions

TABLE 1.—*A 3-year summary of yields, percentage of U. S. 1 tubers and specific gravities of Erli-Red compared with 4 commercial varieties grown in 3 different states.*

Variety	Total yield per acre	U. S. No. 1	Specific gravity
	(cwt)	(pct)	
1959—Osseo, Minnesota			
Erli-Red	422	89	1.064
Waseca	396	96	1.066
Norland	290	90	1.064
1958—Grand Forks, North Dakota			
Erli-Red	177	85	1.089
Norland	220	96	1.088
Triumph	166	93	1.085
1957—Malhauer Exp. Station, Ontario, Oregon (Irrigated)			
Erli-Red	346	85	1.070
Triumph	309	77	1.082
Dazoc	326	87	1.087

is excellent. It is readily handled into and out of storage with a minimum amount of damage from abrasion, common storage rots and black spot.

Marketing characteristics of Erli-Red tubers are uniformity of size and shape, smoothness of skin, and a deep red color. The tubers need no dye.

In 1960 twenty acres were certified for seed production in Minnesota. A fairly good supply of seed is available.

REDSKIN, A NEW RED VARIETY OF POTATO RESISTANT TO SCAB, WITH HIGH YIELDING ABILITY, AND ADAPTED TO GROWING CONDITIONS IN THE SOUTH[1]

R. V. Akeley,[2] Bruce A. Perry,[3] and Allen E. Schark[2]

A potato variety named Redskin (named for skin color) was released on February 23, 1960, by the Crops Research Division of the United States Department of Agriculture and the Agricultural Experiment Station of Texas.

Redskin, tested jointly by these agencies and others under the pedigree number B 2368-4, is a selection from a cross between Pontiac and U.S.D.A. Seedling B 400-1. Pontiac and Red Pontiac, a mutant of Pontiac with a deeper red skin, are well established commercial varieties primarily because of the demand for high-yielding, red-skinned varieties. U.S.D.A. Seedling B 400-1 is a red-skinned selection possessing high fertility, early maturity, and resistance to scab.

The original seedlings under pedigree number B 2368 were first grown in 1948 at the Plant Industry Station, Beltsville, Maryland. In 1949, tubers from these seedlings were grown for increase and selection in Maine. Redskin was selected from these lots for its scab resistance and yielding ability.

The pedigree of Redskin follows:

- Redskin (U.S.D.A. Seedling B 2368-4)
  - U.S.D.A. Seedling B 400-1
    - U.S.D.A. Seedling B 56-11
      - Earlaine
      - X
      - Ostragis
    - X
    - U.S.D.A. Seedling X 499-a
      - Earlaine
      - X
      - Richter's Jubel
  - X
  - Pontiac
    - Katahdin
    - X
    - Triumph

Description

Plants — late maturing, large, spreading. *Stems*: thick and prominently angled; green and pigmented. *Wings*: prominent. *Nodes*: same or slightly larger than stem. *Leaves*: large, open, light bluish-green. *Terminal leaflets*: large, medium ovate, apex acute, base asymmetrical, mean length 56 mm., mean width 35 mm., index 61.[4] *Primary leaflets*: broadly ovate,

[1]Accepted for publication September 12, 1960.

[2]Principal horticulturist, Beltsville, Maryland, and horticulturist, Presque Isle, Maine, respectively, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Beltsville, Md.

[3]Superintendent, Winter Garden Substation of the Texas Agricultural Experiment Station, Crystal City, Texas.

[4]Calculated by dividing the width by the length of each 100 terminal leaflets and multiplying by 100. The terminal leaflets were taken from the fifth leaf from the top of stem. Since the potato leaflet is asymmetrical, the length was determined by taking the average of the measurements from the apex to the base of each respective lobe.

3 pairs. *Secondary and tertiary leaflets*: many. *Midribs and petioles*: light green, scantily pubescent.

FLOWERS — *Buds*: green. *Calyx lobes*: awl-shaped, medium long, green, abundantly pubescent. *Corolla*: medium, light violet with white tips. *Anthers*: orange yellow. *Pollen*: abundant and of good quality.

TUBERS: — Round to oblong, mean length 81 mm.,[5] mean width 77 mm.,[5] mean thickness 63 mm.;[5] indices, width to length, 96.,[6] thickness to length, 79.,[7] thickness to width, 82.[7] *Skin*: smooth, medium red color in periderm. *Eyes*: medium to deep, same color as skin. *Flesh*: white. *Sprouts*: mallow purple. *Maturity*: late, stolon separation, good.

CHARACTERISTICS

Redskin is late in maturity. In Maine, it compares favorably with Katahdin, Chippewa, Sebago, and Red LaSoda in yielding ability, in total solids content, and in color rating of chips and french fries. As shown in Table 1, Redskin yielded 515 cwt. per acre in Maine in 1958. This is significantly greater than the yield of Katahdin, Chippewa, Sebago, or Red LaSoda. Redskin consistently produced high yields in tests for several years. The data in Table 1 show that in 1958 Redskin had a total solids content of 18.0 per cent as compared with Katahdin and Chippewa with 19.6 and 17.0 per cent, respectively. After harvest, Redskin produced chips and french fries with color ratings of 8.9 and 8.8, respectively, as compared with Katahdin with 9.1 and 8.6. After several months of storage at 40° F., followed by reconditioning, Redskin produced chips with a color rating of 9.1 as compared to Katahdin with 7.1.

The data (Table 2) show the reaction of Redskin and three standard varieties to verticillium wilt when planted in infested soil. At the end of the 1958 growing season in Maine, Redskin showed wilt symptoms in 41 per cent of the plants as compared to Katahdin with 18 per cent, Menominee with 51 per cent, and Irish Cobbler with 83 per cent. Moreover, Redskin was highest in yield per acre and was not significantly different in per cent total solids from Katahdin or Irish Cobbler.

The data (Table 3) show the results of the 1958 test in Maine for tuber necrosis caused by seasonal infection with leafroll virus. In this test, green peach aphids were allowed to feed 1 week on Katahdin plants known to have leafroll. The aphids were then transferred to each plant in the field test in order to infect these plants with leafroll virus. In addition, each row in the field plot, adjacent to the varieties tested, was planted with Katahdin plants carrying the leafroll virus. After harvest and 3 months' storage, the tubers were examined. Redskin showed no necrotic symptoms as compared with Plymouth with 3.8 per cent, Delus with 43.6 per cent, and Mohawk with 68.3 per cent.

In other tests, Redskin showed field resistance to common scab and

[5]The average of measurements of 100 tubers, each weighing approximately 8 ounces.
[6]Calculated by dividing the width of each 100 tubers by the length and multiplying the average of the ratios by 100. The data used for calculating the indices were taken from the same measurements as those used to designate the dimensions of the tubers.
[7]Based on measurements of the same tubers as those used for determining the width-to-length index, using the same calculations.

TABLE 1.—*Yield, percentage solids, and chip- and french-fry-color indices of Redskin compared with those of 4 standard varieties of potato grown on the Aroostook Farm, Presque Isle, Maine, 1958.*

Variety	Yield of U. S. No. 1 tubers/acre	Total solids	Chip color after harvest	Chip color after reconditioning[1]	French fry color after harvest[1]
	Cwt.	Pct.			
Redskin	515	18.0	8.9	9.1	8.8
Katahdin	426	19.6	9.1	7.1	8.6
Chippewa	406	17.0	8.1	8.1	7.5
Sebago	390	19.9	8.1	8.9	7.2
Red LaSoda	369	18.1	9.4	8.1	9.0
LSD at .05	53	1.0			

[1]Color indices are based on the standard color chart of the National Potato Chip Institute. Chips and French fries with lower index numbers are lighter in color.

TABLE 2.—*Reaction to Verticillium wilt as reflected in yields and percentage solids of Redskin and 3 varieties of potato grown in wilt-infested soil on the Ashby Farm, Caribou, Maine, 1958.*

Variety	Yield of U. S. No. 1 tubers/acre		Total solids	Plants infected with wilt
	Cwt.	Pct.	Pct.	Pct.
Redskin	358	98	16.8	41
Katahdin	349	98	17.6	18
Irish Cobbler	297	94	17.6	83
Menominee	306	97	17.9	51
LSD at .05	50		0.9	

TABLE 3.—*Yields and tuber symptoms for net necrosis of Redskin and 3 varieties of potato exposed to leafroll in the field, Aroostook Farm, Presque Isle, Maine, 1958.*

Variety	Yield of U. S. No. 1 tubers/acre		Tubers showing net necrosis Examined	Infected
	Cwt.	Pct.	No.	Pct.
Redskin	444	98	367	0.0
Plymouth	368	97	366	3.8
Delus	307	97	330	43.6
Mohawk	297	93	306	68.3
LSD at .05	56			

to virus A (mild mosaic) but showed susceptibility to late blight, virus X, and virus Y.

The data in Table 4 show that Redskin compared favorably with 5 standard varieties grown in Texas from January to May in 1957 and 1958. Redskin outyielded Katahdin, Kennebec, and Plymouth at Laredo and Primera in 1957. At Weslaco in 1958 Redskin outyielded Sebago, Katahdin, and Plymouth. Its mean yield of 143 cwt. per acre for the

TABLE 4.—*Yields, percentage solids, maturity, scab, and wind resistance of Redskin compared with 5 standard varieties of potato grown in Texas, 1957 and 1958.*

Variety	Total yield/acre				Total solids	Maturity scab wind resistance		
	1957 Laredo	1957 Primera	1958 Weslaco	Mean[1]	1958 Weslaco	1957 Laredo	1957 Laredo	1957 Primera[2]
					Pct.			
Redskin	157	129	144	143	19.5	M. early	None	1
Sebago	164	143	120	142	18.9	Medium	V. light	1
Katahdin	147	126	123	132	18.7	M. late	V. light	2
Kennebec	135	119	..	..	..	M. early	Light	2
Plymouth	133	115	114	121	18.9	M. early	V. light	2
Red Pontiac	..	..	149	..	17.2	..	..	..

[1]For 3 locations.
[2]Wind resistance: (1) withstood damage by daily winds of high velocity; (2) damaged severely by winds but recovered; (3) damaged severely and never recovered.

3 locations is similar to that of 142 cwt. for Sebago. At Weslaco in 1958 Redskin yielded 144 cwt. per acre as compared with Red Pontiac with 149 cwt. Moreover, it had the highest solids content of all varieties grown at this location. It matured medium-early and had no scab lesions at Laredo. At Primera, it was rated as highly resistant to wind damage.

The "freeze-back" of young potato plants that occurs some years in Florida and Texas seriously affects yields. Varietal differences in "freeze-back" recovery are strikingly apparent in the field. Redskin showed excellent recovery and yielding ability following "freeze-backs" at Hastings, Florida, in 1958, and at Brownsville, Texas in 1959.

The smooth skin, medium-red color, medium-early maturity, resistances to wind damage and scab, high-yielding ability, high solids content, and recovery from frost damage of Redskin make it a very desirable variety for potato production in the South, especially in areas where Red Pontiac is grown. Its yielding ability, and its resistance to scab and to net necrosis in the tuber, and its partial resistance to verticillium wilt when grown in the North make it a variety easy to grow for seed potatoes.

Because of the extreme vigor and high-yielding ability of Redskin, its tubers tend to become large and deep-eyed if allowed to grow too long under ideal conditions. This tendency to produce rough oversized tubers must be controlled if the variety is grown for tablestock in some northern areas.

UREA FORMALDEHYDE CONCENTRATE-85 FOR SCAB CONTROL IN POTATOES[1]

T. H. SCHULTZ, K. C. BERGER, H. M. DARLING AND M. H. FLEISCHFRESSER[2]

Common scab of potato has mainly been controlled through acidification of the soil to pH 5.2 or below and by planting resistant varieties. Acid soil conditions, however, limit the yields of crops grown in the rotation, including potatoes. The application of liming materials to favor certain crops may increase the amount of scab in the succeeding crops of potatoes (3).

Since 1950, intensive research for satisfactory scab control through applications of organic soil fungicides to control the soil-borne pathogen *Streptomyces scabies* (Thaxt.) has been under investigation.

One of the promising materials is Urea Formaldehyde Concentrate-85. It is a water miscible, viscous liquid and is a formaldehyde polymethylol urea compound composed of approximately 26% urea and 60% formaldehyde which is slowly released. The urea-to-formaldehyde mole ratio is 0.217. UFC-85 contains about one pound of nitrogen per gallon.

The first application of UFC-85 as a soil fumigant was for celery seedbed sterilization in Florida (2) in 1956. Its value as a fumigant for control of common scab in potatoes has since been under investigation. Promising results were obtained with UFC-85 by Bartz and Berger in 1958 (1) using broadcast applications at time of planting.

Broadcast applications of UFC-85 are not economically feasible for potatoes at the rates necessary for optimum control of potato scab. The present study was, therefore, undertaken to evaluate rates of row applications versus broadcast applications which had previously given the desired control.

MATERIALS AND METHODS

Field studies in 1958 and 1959 were conducted on sand, sandy loam, silt loam, and peat soils to further investigate the effectiveness of UFC-85 on various soils for potato scab control. These experiments were located in all of the major potato producing areas of Wisconsin in fields which were believed to be uniformly infested with *S. scabies*, and were planted with scab susceptible potato varieties such as Red Warba, Chippewa, Red Pontiac, Katahdin, and Red LaSoda.

In the experiments summarized in Tables 1 and 2, each treatment was replicated four times in a randomized block design. All plots, including the control, received equal amounts of nitrogen, phosphate, and potash which was applied prior to or during planting.

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[2] Research Assistant Soils, Professor Soils, Professor Plant Pathology, and former Research Assistant Soils, respectively.

Table 1.—*Yield, scab index, and quality of Red Warba potatoes grown on Vilas sand soil, with various rates of UFC-85. State Potato Farm, Three Lakes, Wisconsin, 1958.*

UFC-85 Gal. applied per acre	Yield bushels per acre	Scab index[1]	% tubers free from scab[2]	Specific gravity
None	255	12.8	49	1.080
10 Row	265	9.3	69	1.075
20 Row	271	5.8	77	1.071
40 Row	288	1.8	93	1.069
80 Row	326	1.0	97	1.076
75 Broadcast	267	8.0	68	1.073
150 Broadcast	274	4.0	82	1.069

All figures average of four replicates.

[1]100 = All severely scabbed; 0 = All scab free.
[2]Tubers having 5% or less of surface area covered with scab.

Table 2.—*Stand, yield, scab index, and quality of Red Warba potatoes grown on Dane silt loam soil with varying rates of UFC-85. Middleton, Wisconsin, 1959.*

UFC-85 Gal. applied per acre	% relative stand	Yield bu. per acre	Scab index[1]	% tubers free from scab[2]	Specific gravity
None	100	523	30.0	24.0	1.064
40 Row	100	561	7.7	70.0	1.067
150 Broadcast	100	608	2.6	95.0	1.061
100 Residual[3]	100	543	14.2	52.0	1.065

All figures average of four replicates.

[1]100 = All severely scabbed; 0 = All scab free.
[2]Tubers having 5% or less of surface area covered with scab.
[3]Applied broadcast at time of planting in 1958.

The UFC-85 was mixed with water in a ratio of one part UFC-85 to two parts of water and applied at various rates with a garden-type sprinkling can. The covering discs were removed from the potato planter to permit application of the UFC-85 immediately above the potato seed in the soil after the seed was planted. Row applications of UFC-85 were applied directly in the row in a 12 inch continuous band. Broadcast applications were made and thoroughly disced into the soil before planting.

In the experiments summarized in Tables 3, 4, and 5 each treatment consisted of four rows replicated twice for the length of the field. The UFC-85 was applied in the row with commercial type equipment and was sprayed in a 12 inch continuous band behind the opening discs of the potato planter, at rates ranging from 20 to 75 gallons per acre.

Stand counts of the potato plants were taken on all plots at an early stage of growth. At harvest yields were obtained by weighing the tubers from 20 feet of the center two rows in each treatment. Scab index and specific gravity measurements were made on random samples

TABLE 3.—*Stand, yield, scab index, and quality of Red Pontiac potatoes grown on Onamia loam soil, with various rates of UFC-85. Arnott, Wisconsin. 1959.*

UFC-85 Gal. applied per acre	% relative stand	Yield bu. per acre	Scab index[1]	% tubers free from scab[2]	Specific gravity
None	100	604	27.0	26.0	1.053
20 Row	96	689	13.0	52.0	1.053
30 Row	91	619	9.5	67.0	1.051
40 Row	87	595	3.4	86.0	1.053
50 Row	64	623	0.5	98.0	1.053

All figures average of four replicates.

[1]100 = All severely scabbed; 0 = All scab free.
[2]Tubers having 5% or less of surface area covered with scab.

TABLE 4.—*Stand, yield, scab index, and quality of Red LaSoda potatoes variously treated with UFC-85 and grown on Antigo silt loam soil, Deerbrook, Wisconsin. 1959.*

UFC-85 Gal. applied per acre	% relative stand	Yield bu. per acre	Scab index[1]	% tubers free from scab[2]	Specific gravity
None	100	435	38.3	10.0	1.060
20 Row	100	613	21.4	25.0	1.062
30 Row	92	539	7.8	67.0	1.061
50 Row	92	479	5.5	78.0	1.059
60 Row	88	383	0.8	96.0	1.057

All figures average of four replicates.

[1]100 = All severely scabbed; 0 = All scab free.
[2]Tubers having 5% or less of surface area covered with scab.

TABLE 5.—*Stand, yield, scab index, and quality of Katahdin potatoes grown on Morley silt loam with varying rates of UFC-85. Sturtevant, Wisconsin. 1959.*

UFC-85 Gal. applied per acre	% relative stand	Yield bu. per acre	Scab index[1]	% tubers free from scab[2]	Specific gravity
None	100	435	18.0	43.0	1.053
20 Row	100	400	7.1	74.0	1.052
30 Row	100	497	4.5	82.0	1.049
45 Row	92	407	3.9	86.0	1.049
50 Row	83	394	1.3	92.0	1.051
60 Row	75	445	0.6	97.0	1.053

All figures average of four replicates.

[1]100 = All severely scabbed; 0 = All scab free.
[2]Tubers having 5% or less of surface area covered with scab.

of 25 tubers taken from each treatment. The Bartz (1) modification of the method of Walker, Larson, and Albert (4) was used to determine the scab index in each case.

Results and Discussion

Potato scab index was materially reduced with 30 to 40 gallon rates of UFC-85 applied in the rows and nearly eliminated with rates above 40 gallons per acre. Row applications of 10 and 20 gallons UFC-85 per acre reduced the scab index somewhat but did not give the desired control. No delay in emergence or reduction in stand was evident at the lower rates. Row applications appeared to be more efficient than broadcast treatments, although 150 gallons UFC-85 broadcast per acre gave excellent control of potato scab. Residual control was only partly effective, reducing the scab index about 50%.

Relative stand and yield were reduced in direct proportion to the amount of UFC-85 applied in the row in excess of 40 gallons per acre. Broadcast application of UFC-85 at rates of 75 to 150 gallons per acre did not reduce the stand, and yields were increased over the check which received the same amount of nitrogen applied as ammonium nitrate.

Increased rates of UFC-85 applied in 1958 resulted in a lowering of specific gravity of the tubers. These data are given in Table 1. In 1959 no appreciable differences in specific gravity measurements were obtained.

Summary

Previous results have shown that common scab of potato can be controlled by broadcasting 150 gallons per acre of Urea Formaldehyde Concentrate-85 at time of planting. In order to find economically feasible rates of application, smaller quantities were applied in the row. UFC-85, a formaldehyde polymethylol urea compound, is composed of 26% urea and 60% formaldehyde. This material is viscous, water miscible, and contains about one pound of nitrogen per gallon.

Field experiments conducted in 1958 and 1959 show that row application of 10 and 20 gallons UFC-85 per acre reduced scab somewhat but did not give the desired control. No delay in emergence or reduction in stand was evident.

Row applications of 30 to 40 gallons UFC-85 per acre did not affect stand and apparently at this rate the UFC-85 was not phytotoxic. Emergence was slightly delayed but scab control was excellent. Higher rates in the row improved potato scab control but markedly reduced the stand and delayed emergence. Broadcast treatments of UFC-85 also gave good control but are economically impractical at the present time.

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EFFECT OF RESIDUAL SULPHUR DIOXIDE ON THE QUALITY OF PREPEELED POTATOES[1]

F. J. FRANCIS AND B. L. AMLA[2]

A wide range of sulphite concentrations and buffer salts have been recommended to control discoloration in prepeeled potatoes. However, high concentrations of salts in the dipping solutions can lead to deterioration in quality (4). Consequently, processors would like to use as low a concentration of sulphite as possible commensurate with an adequate safety factor for discoloration control. Anderson and Zapsalis (5) recommended a 60 second dip in a solution containing 600 p.p.m. sulphur dioxide followed by packaging in Cryovac bags and storage at a low temperature. Amla and Francis (2) pointed out that the concentration of sulphite could be further reduced by replacing part of the sulphite with phytic acid or calcium phytate. However, whether the control of discoloration is effected by chemical means, or by a combination of chemical treatment and low oxygen tension, there are problems concerned with the maintenance of quality. Discoloration, evaluation, softness and alcohol content have been discussed in previous papers (2, 3, 4, 6). This report is concerned with the uptake of sulphur dioxide and the associated problems of quality.

MATERIALS AND METHODS

Idaho Russet Burbank potatoes for this work were purchased through regular commercial channels. The potatoes were abrasion peeled for the data in Tables 1, 2 and 3, and hand peeled for the data in Table 4 and part of Table 1. After peeling, the potatoes were cut into one-half inch French-Fry style strips and kept immersed in water until required. After dipping in the appropriate solution for one minute, the strips were drained for 5 minutes and packed into polyethylene[3] bags, Cryovac[4] bags or glass[5] jars. The control samples were dipped in water and handled in the same way. Approximately 450 grams (1 lb.) were packed in each container.

The sulphite solutions were made by dissolving the appropriate amount of sodium bisulphite in distilled water or buffer solution. The buffer solutions were prepared as described in a previous paper (4).

The samples were analyzed for residual sulphur dioxide by the Monier-Williams method (1), using 100 grams of a slurry obtained by blending the contents of each package. The alcohol determinations were made by the method of Shupe and Dubowski (8). The softness determinations were made with a Universal Precision Penetrometer[6] with

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[2]University of Massachusetts, Amherst, Mass.
[3]2x4x12 inch bags of one mil polyethylene obtained through the courtesy of the Shellmar-Betner Division of the Continental Can Co., Newark, Ohio.
[4]5x16 inch bags obtained through the courtesy of the Cryovac division of the W. R. Grace & Co., Cambridge, Mass.
[5]Pint Mason jars with two-piece metal lids.
[6]Manufactured by the A. S. Aloe Co., St. Louis 3, Mo.

150 grams weight on the bar. The pH measurements were made with a Beckman, Model G, pH meter.[7]

The taste panels were conducted with samples which had been dipped in the appropriate sulphite solution and stored in the refrigerator for 24 hours before cooking and mashing. With the sulphite treatments of 2000 ppm and above, each batch of potato strips was cooked separately and served to the panel. Samples intended to have treatments below 2000 ppm sulphur dioxide were prepared by a dilution technique. A stock sample treated with 2000 ppm sulphur dioxide was diluted after cooking and mashing with fresh cooked and mashed potatoes in such proportions that the mixture contained residual amounts of sulphur dioxide equivalent to dipping fresh strips in 1500, 1000 and 500 ppm sulphur dioxide. Fresh non-treated controls were served with each treated sample for comparison and the judges were asked to identify the off-flavor sample from each pair.

The dilution technique was necessary in order to minimize color differences in the samples. It was deemed inadvisable to cook the samples immediately after the sulphite treatment, therfore, any samples kept for twenty four hours had to have sufficient sulphite treatment to preserve the white color.

The taste panel results were tested for significance by the method of Krum (7). All other results were tested by the method of Tukey (9).

Results and Discussion

Effect of immersion time.

The data in Table 1 indicate that the main factor involved in the residue of sulphur dioxide was the strength of the dipping solution. It was logical to expect that higher concentrations of sulphite in the dipping solution would increase the residue in the potatoes. However, the length of immersion did not have any correlation with the residue of sulphur dioxide. Potato tissue will take up considerable amounts of liquid (6) but the immersion time would have to be unduly prolonged to affect the uptake appreciably. Apparently for immersion times from 10 seconds to 10 minutes the residues of sulphur dioxide will be similar. This observation could have implications for recommendations that if a weaker solution of sulphite is used, the immersion time should be increased. This will be the subject of another paper.

The data in Table 1 indicate that the sulphur dioxide residues were comparable for potatoes peeled in a certain way regardless of the length of immersion. However, a different peeling method resulted in markedly different residues. The abrasion peeled potatoes had much higher residues than the hand peeled strips. This would be expected because the former had a much rougher surface and therefore the surface area exposed to the sulphite solution was much greater.

Effect of storage time.

In Table 2, data are provided on the decrease in residual sulphur dioxide with storage time. The sulphur dioxide residue decreased to one-third or less in fifteen days time; probably due to a slow reaction with

[7]Manufactured by Beckman Instruments, Inc., Fullerton, Cal.

TABLE 1.—*Residual sulphur dioxide[1] in potato tissue after dipping in sodium bisulphite solutions for varying lengths of time.*

Duration of dip. Minutes	Concentration of sulphur dioxide in dipping solution[2] (ppm) 5000	2500	1250	836	625
	Residual sulphur dioxide (ppm)[3]				
10	299	121	42		
8	290	132	35		2.2
6	232	125			2.2
4	257	124			1.8
2	264	112			2.2
		abrasion peeled			
1		hand peeled			1.8
0.5	..	45	11	4.4	1.8
0.33	..	52	8	3.0	
0.17	..	50	10	3.5	

[1]Unpublished data supplied by W. Draper and W. Averill.

[2]Sulphur dioxide solutions were made by dissolving appropriate amounts of sodium bisulphite in known amounts of distilled water.

[3]Analyzed approximately 16 hours after treatment.

TABLE 2.—*Residual sulphur dioxide and alcohol in French-fry style potato strips after storage at 38-40° F.*

Type of package	Conc. of dipping solution	Storage time in days 1	5		10		15	
		Residual sulphur dioxide and alcohol						
	SO_2 ppm	SO_2 ppm	SO_2 ppm	Alc. mg/100 g	SO_2 ppm	Alc. mg/100 g	SO_2 ppm	Alc. mg/100 g
Poly-ethylene bags	500	..	25	25	12	30	0	31
	2000	44	65	27	65	28	6	32
	5000	162	115	28	83	26	56	27
	Control	0	0	22	0	31	0	33
Cryovac bags	500	12	9	26	6	30	15	32
	2000	32	15	27	10	30	13	30
	5000	167	121	26	92	26	50	28
	Control	0	0	30	0	30	0	31
Glass jars	500	12	6	27	11	36	12	31
	2000	22	11	24	6	32	6	32
	5000	94	74	25	21	28	30	30
	Control	0	0	27	0	32	0	31

the components of the potato tissue. The decrease was less in the polyethylene bags and since the Cryovac bags and the glass jars would be much less permeable to gaseous sulphur dioxide, than the polyethylene bags, it is probable that gaseous diffusion of sulphur dioxide was a relatively minor factor in the decrease.

Data on alcohol content are also included in Table 2. The level of sulphite had little effect on the development of alcohol as pointed out in a previous paper (2) but the concentration of alcohol did not increase appreciably with time of storage. Another anomaly was also apparent in that appreciable alcohol levels could be demonstrated in the samples stored in polyethylene bags. In previous work alcohol was not found in samples stored in polyethylene bags except where tissue injury was evident (2, 4). The alcohol levels in this experiment were probably not too important as they were all below the level (40 mg/100g) likely to be detected by a taste panel (3) but it is further evidence that the production of alcohol may be due to a number of causes (4).

In Table 3, data on the firmness of the potato slices was included because appreciable alcohol levels are usually accompanied by a softening of the tissue. The samples stored for 15 days in polyethylene bags were firmer than those in Cryovac bags and glass jars. The data for the other samples indicated softer tissue than reported previously (2) but hardly enough to account for the alcohol level.

Effect of pH

In Table 4, data are presented on the effect of buffering the sulphite dipping solutions on the residual sulphur dioxide in the tissue. It was evident that the potatoes dipped in the solutions buffered at low pH values showed much higher residues of sulphur dioxide. At pH values of 8 and over, no residual sulphur dioxide could be detected. It is possible that the reaction of the sulphite residues with the components of the potato proceeded much faster at the higher pH. Raising the pH of the dipping solution is obviously one way of reducing the problem of excess sulphite residues but it would also introduce other problems such as exudation and discoloration (4).

Taste panel results.

In Table 5, data are presented on the results of a taste panel with cooked mashed potatoes which had an appreciable amount of residual sulphur dioxide in the raw potato strips. The minimum level of sulphur dioxide which could be detected by the taste panel was between 87 and 115 ppm. It is probably a reasonable assumption that the average consumer could not detect sulphite flavor in cooked potatoes prepared from raw products having a residual sulphur dioxide content of 85 ppm or less. However, it should be noted that the above results were obtained with a small panel (27 judges) and there is known to be considerable variation in the ability of individuals to detect the taste of sulphur dioxide.

Summary and Conclusions

French-fry style potato strips were immersed for varying lengths of time in five concentrations of sodium bisulphite solutions. The residual

TABLE 3.—*Firmness of French-fry style potato strips after storage at 38-40° F.*

Type of package	Conc. of dipping solution SO_2 ppm	Storage time in days 1	5	10	15	L.S.D.—5%
		Firmness[1], mm.				
Polyethylene bags	500	38	38	40	40	2.1
	2000	35	37	40	40	2.5
	5000	34	35	40	40	2.4
	Control	37	37	40	40	2.6
	L.S.D.—5%	3.0	2.3	2.0	2.7	
Cryovac bags	500	38	36	38	42	2.5
	2000	36	38	40	44	2.1
	5000	34	37	43	47	2.6
	Control	37	37	40	43	3.4
	L.S.D.—5%	3.0	2.3	2.4	3.3	
Glass jars	500	38	40	48	58	4.6
	2000	35	41	42	49	4.5
	5000	34	41	44	45	2.9
	Control	37	40	44	50	4.2
	L.S.D.—5%	3.0	4.1	3.6	5.9	

[1]Each datum represents the average of 27 readings. A high value indicates a soft tissue.

TABLE 4.—*Effect of pH of the dipping solutions on the residual sulphur dioxide in prepeeled potato slices.*

Storage Temperature °F.	pH of dipping solution[1]	Residual sulphur dioxide ppm
40-42	4.15	118
↓	5.40	96
	6.50	74
	6.70	89
	6.82	81
	3.75[2]	96
32-34	4.00	241
↓	6.00	100
	7.00	26
	8.00	0
	10.00	0
	3.70[2]	109

[1]All samples had been dipped in a solution containing 4000 ppm sulphur dioxide buffered at the appropriate pH value and stored in polyethylene bags for 16 days.
[2]Unbuffered solutions.

sulphur dioxide in the strips increased with increasing strength of solution but not with increasing time of immersion. Potatoes peeled by hand had much lower residues of sulphur dioxide than abrasion peeled samples due probably to the smoother surface of the former. Potato strips dipped in sulphite solutions buffered at pH values from 4 to 10 showed de-

TABLE 5.—*Organoleptic evaluation of threshold concentrations of residual sulphur dioxide in treated potatoes.*

Concentration of dipping solution. Sulphur dioxide	Panel results for cooked mashed potatoes[1]		Residual sulphur dioxide in raw potato tissue
ppm	Correct	Incorrect	ppm
5000	21[2]	6	312
2500	24[2]	3	152
2000	16[2]	4	115
1500	7	13	87
1000	10	10	58
500	9	11	29

[1]Number of judges detecting or failing to detect presence of SO_2 in treated potatoes.
[2]Significant at 1% level.

creasing residues of sulphur dioxide with increasing pH value. No residues were detectable at pH values of 8 and 10. Taste panels could detect a sulphite flavor in cooked mashed potatoes which had a sulphite content of 115 ppm in the raw product. No off-odor could be detected in samples containing 87 ppm sulphur dioxide.

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THE RELATION OF SOLUBLE MANGANESE TO THE INCIDENCE OF COMMON SCAB IN POTATOES[1]

J. J. MORTVEDT, M. H. FLEISCHFRESSER, K. C. BERGER, AND H. M. DARLING[2]

Common scab of potato, caused by *Streptomyces scabies*, is one of the oldest known diseases of potatoes. Growing scab resistant varieties on scab infected soil is one means of controlling this disease. Another means of control is to acidify the soil to a very strongly acid condition which often results in reduced yields. The reason for the control of scab by soil acidification is not clearly understood. Greis (5) postulated that soluble aluminum ions may have some relation to the control of scab at a soil pH of 5.2 and lower.

In strongly acid soils the level of soluble manganese is often high enough to cause manganese toxicity in potatoes, Berger and Gerloff (2). It was postulated that such concentrations of manganese might have an inhibiting effect on the scab organism. Greenhouse studies were initiated to determine if varying levels of soluble manganese in the tuber zone would reduce the amount of scab on susceptible potato varieties.

A field experiment was conducted to determine if the row application of manganese with the fertilizer would have any effect on the incidence of scab by systemic control.

MATERIALS AND METHODS

In order to study the effect of soluble manganese upon the scab organism without influencing the nutrition of the potato plant, it was necessary to separate the tuber setting zone from the root zone and treat them separately. Wooden boxes 10 inches wide, 13 inches long and 4 inches deep were constructed and placed over two gallon glazed crocks containing six liters of nutrient solution. Scab susceptible Chippewa potatoes were sprouted in quartz sand. When they were about 10 inches high, two plants were placed through holes in the top and bottom of each box, so that the roots were in the nutrient solution and the rhizomes were in the box.

Cultures of *Streptomyces scabies* of proven pathogenicity were grown on potato dextrose agar in Petri dishes and placed into suspension with various manganese solutions in a Waring blendor. The suspension was thoroughly mixed with white quartz sand to a moisture content of 12% by weight. This inoculated sand was then placed in the boxes.

The nutrient solution was changed weekly at the start of the experiment and with increasing frequency as the plants grew. The solutions were aerated through perforated tygon tubing sealed at one end. The reaction of the solution was maintained between pH 4.5 and 5.5.

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[2]Research Assistant in Soils, Former Research Assistant in Soils, Professor Soils, and Professor Plant Pathology, respectively.

One experiment was conducted in the greenhouse and a similar experiment was conducted in the plant growing room where light was provided by fluorescent and incandescent lamps. The initial length of the light period was 16 hours but was reduced to 12 hours as the experiment progressed. Daytime temperatures averaged about 23° C. and night temperatures were about 16° C. The plants were harvested 110 days after they had been placed in the nutrient solutions.

The Bartz (1) modification of the method of Walker, Albert and Larson (6) was used to determine the scab indices. Tubers were divided into the following five classes: 0-5% of the surface scabbed (surface scab only); 5-25% of the surface scabbed plus pitted scab less than 5% of the surface scabbed; 25-50% of the surface area scabbed; 50-75% of the surface scabbed; and 75-100% of the surface area scabbed.

The number of tubers in each class was then multiplied by 0, 1, 2, 3, and 4 respectively. The sum of the products was divided by four times the total number of tubers, and the quotient was multiplied by 100 for the scab index. A scale of zero for clean tubers to 100 for severely scabbed tubers results.

In a field experiment, manganese sulfate at rates of 50 and 150 pounds per acre was mixed with the fertilizer and applied in bands beside the seed at planting. The experiment was replicated three times and a scab susceptible variety of potatoes, Red Warba, was planted. Tissue samples of the top growth were taken at three intervals to determine if and when the added manganese was taken up by the plants. Only the upper third of the plant was taken for the tissue analyses, since it was thought that the youngest parts of the plant would reflect any changes in the manganese content between sampling dates. The potatoes were planted May 28, 1960; and the tissue was sampled July 1; July 16, when the potatoes were blossoming; and August 1, at harvest. The yields and scab indices were determined at harvest, the latter being determined by the method previously described. Samples of tuber parenchyma tissue and tuber epidermal tissue were also analyzed for manganese.

Results and Discussion

The results of the greenhouse experiment are shown in Table 1. The amounts of manganese added to the sand surrounding the tubers ranged from zero to 10 ppm. A scab index of 26.0 was found where manganese was not added. Each added increment of manganese resulted in a decrease in scab index until at the 10.0 ppm level of manganese, the scab index was 7.5. The difference required for significance was high, but there was a constant decrease in the scab index as the manganese levels were increased. The scab index was significantly reduced by all manganese levels of 2.0 ppm and higher.

Distilled water was added to the sand in the tuber zone twice during the experiment to maintain the moisture level. At harvest, it was noted that the scab lesions occurred on the upper side of the tubers near the surface of the sand in treatments with high manganese. The underside of these tubers and all of the surfaces of the tubers in the lower part of the box remained scab free. It is thought that the addition of distilled

TABLE 1.—*Degree of scab infection on Chippewa potatoes and manganese content of top growth as influenced by levels of manganese in the tuber zone.*

Greenhouse experiment.

Mn added to sand[1] (ppm)	Scab index[2]	% Tubers free from scab	Manganese content (ppm)
0.0	26.0	50	281
0.5	19.7	50	276
2.0	16.0	60	373
5.0	14.0	72	396
10.0	7.5	85	495
LSD 5% level	9.6		63

[1]Manganese as $MnSO_4$ added in solution.
[2]100 = All severely scabbed, 0 = Scab free.

water leached the manganese from the upper portions of the sand and permitted the scab to develop on the upper surfaces of the tubers which formed near the top of the sand.

Analysis of the surface sand and that three inches below the surface taken from those treatments with added manganese indicated that the manganese content of the sand in the upper portions of the box was less than the amount added initially, but this difference was not noted in the sand taken from the lower level. The addition of distilled water apparently leached the soluble manganese from the sand in the upper portions in the boxes and permitted the scab to develop. With the higher manganese treatments, potatoes were scab free in the lower portions of the boxes. The percentage of tubers free from scab increased from 50% in the treatment without manganese to 85% in the 10.0 ppm manganese treatment.

The results of the plant growing room experiment are shown in Table 2. Various amounts of manganese ranging from zero to 20.0 ppm were added to the sand surrounding the tubers. The scab index in the zero manganese treatment was 11.6. Each added increment of manganese resulted in a decrease in scab until at 20.0 ppm of added manganese, the scab index was zero. The addition of 2.0 ppm of manganese decreased the scab index about 50%.

Manganese solutions equal in strength to those originally added to the sand were added once during the experiment to replace that which was lost due to evaporation. This decreased the leaching of the manganese from the surface of the sand. At harvest, no relationship between the location of the tubers and the amount of scab was noted. The percentage of tubers free from scab increased from 64.3% in the treatment without manganese to 100% in the 20.0 ppm manganese treatment.

The tissue of the top growth was analyzed for manganese content. The results of this chemical analysis are shown in Tables 1 and 2. The

TABLE 2.—*Degree of scab infection on Chippewa potatoes and manganese content of top growth as influenced by levels of manganese in the tuber zone.*

Plant growing room experiment.

Mn added to sand[1] (ppm)	Scab index[2]	% Tubers free from scab	Manganese content (ppm)
0.0	11.6	64	257
2.0	6.3	80	344
5.0	4.5	86	381
10.0	1.8	93	453
20.0	0.0	100	522
LSD 5% level	2.9		81

[1]Manganese as $MnSO_4$ added in solution.
[2]100 = All severely scabbed, 0 = Scab free.

manganese content of the tissue increased as the amount of manganese added to the sand in the tuber forming zone was increased. Adventitious roots developed in the sand in the tuber forming zone which probably resulted in the uptake of manganese from this area. However, these relatively high concentrations were not toxic, as no toxicity symptoms developed. The range of manganese content found in the tissue is included in the range present in normal plants.

The results of the field experiment are shown in Table 3. The addition of manganese sulfate to the fertilizer had no significant effect on the yield or the amount of scab development on the potatoes. The yields of the treatments with 0, 50, and 150 pounds of manganese sulfate per acre were 280, 319, and 294 bushels per acre, respectively. The scab index of the potatoes for these same treatments was 8.2, 7.6, and 7.2 respectively. This is much lower than that of the previous year, where untreated potatoes of the same variety in the same location had a scab index of 30.0. A high amount of rainfall during the growing season maintained the soil moisture level at or near field capacity. This may have accounted for the lower scab indices in all the treatments. There was no evidence of manganese toxicity in any of the plots where manganese had been applied.

Analyses of the top growth samples at three different times and also that of the tuber parenchyma and epidermal tissue are shown in Table 4. Without a manganese sulfate application, the manganese content of the potato plants decreased with maturity from 115 to 102 ppm. Where manganese sulfate had been applied, however, the manganese content of the tissue increased as the plant matured. At the 50 pound per acre level of manganese sulfate the plant content of manganese increased from 130 to 234 ppm and in the 150 pounds per acre treatment, the manganese content increased from 154 to 325 ppm.

The manganese content of the tuber epidermal tissue increased from

TABLE 3.—*Yield and scab index of Red Warba potatoes as influenced by varying levels of manganese sulfate applied in the fertilizer band.*

Amount of $MnSO_4$ applied (lbs/A)	Yield bu/A)	Scab index[1]	% Tubers free from scab
0	280	8.2	21
50	319	7.6	24
150	294	7.2	30

[1]100 = All severely scabbed, 0 = scab free.
All figures are an average of three replicates.

TABLE 4.—*Manganese content of potato top growth and tuber tissue as influenced by varying levels of manganese sulfate applied in the fertilizer band.*

Amount of $MnSO_4$ applied (lbs/A)	Manganese Content (ppm)				
	Top growth			Tuber parenchyma tissue	Tuber epidermal tissue
	July 1	July 16	Aug. 1		
0	115	104	102	11	110
50	130	134	234	11	155
150	154	203	325	12	165

All figures are an average of three replicates.

110 to 165 ppm as the amount of applied manganese sulfate increased from zero to 150 pounds per acre. The application of manganese sulfate had no effect on the manganese content of the tuber parenchyma tissue. It remained at 11 or 12 ppm with all three treatments.

The results of this experiment are not conclusive because the amount of scab present was very low. The scab indices found were not significantly different; however there was a trend toward scab reduction with increased manganese application. Further experiments are in progress.

SUMMARY

The incidence of potato scab was significantly reduced by the addition of soluble manganese added to quartz sand in the tuber forming zone of Chippewa potatoes in two greenhouse experiments. Specially designed wooden boxes were constructed enabling the tuber setting zone to be separated and treated differently from the roots. The roots were placed in glazed crocks containing complete nutrient solutions.

Cultures of *Streptomyces scabies* were suspended in various manganese solutions, mixed with quartz sand, and placed in the tuber forming region. In both experiments the development of scab was significantly reduced by concentrations greater than 2.0 ppm soluble manganese. These

experiments indicate that high concentrations of soluble manganese in the soil solution in the tuber setting zone may be one reason why scab is less prevalent in highly acid soils.

Three levels of manganese sulfate were row applied with the fertilizer to Red Warba potatoes at planting time in a field experiment. The yield and scab index of the potatoes were not significantly changed by any of the treatments. Chemical analysis of the top growth indicated that the manganese content of the tissue was increased in the treatments where manganese had been added. This increase was evident before blossoming and the initial formation of tubers. Analyses of the tubers showed that the addition of manganese to the applied fertilizer caused increases in the manganese content of the tuber epidermal tissue, but had no effect on that of the tuber parenchyma tissue.

These results indicate that although significant differences were not obtained in this experiment, the trend was toward reduced scab with higher manganese applications.

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REPORT ON MAINE POTATO FUTURES ISSUED

The Maine potato futures market was of substantial size in the early part of the 1960-61 marketing season for Maine potatoes, although activity in potato futures was not as large as one year earlier.

This was reported recently by the U. S. Department of Agriculture in issuing a report of the Commodity Exchange Authority appraising utilization of the Maine potato futures market in the June-December 1960 period. The report includes results of a CEA survey of the positions of all traders in the market, which is conducted by the New York Mercantile Exchange, as of the end of October 1960.

There were 1,197 traders in Maine potato futures on the survey date, with total open contracts of 7,103 carlots. These totals were slightly below the figures of one year earlier.

Largest part of the market, the survey showed, was in the hands of traders in the potato industry — growers, shippers, processors, etc. — who accounted for 55.5% of total long positions and 64.5% of total short positions.

The large proportion of short positions held by industry traders reflected the continuing substantial utilization of potato futures by industry groups concerned with the hedging of inventories and fixed-price purchase commitments in cash potatoes.

Participation of growers was not as large as one year earlier but continued to consist primarily of short hedging, which is the normal interest to potato growers in the futures market. As in previous surveys, potato shippers — some of whom are also producers — held the largest aggregate of short hedging commitments, followed by receivers and merchants.

A substantial increase in long hedging commitments in Maine potato futures, largely by processors, was shown by the October 1960 survey as compared with the survey one year earlier. The larger amount of long hedging by potato processors indicated their increased use of the market to protect prices on processing requirements.

Traders in Maine were making the major utilization of the market for hedging purposes at the end of October 1960. Maine traders held almost half of the combined long and short hedging commitments in the market. Positions of Maine traders classified as speculative were a minor factor in the market at the time of the survey.

With fall potato production in 1960 larger than in 1959 in most leading areas, although not in Maine, prices in the fall and early winter were below the level of one year earlier, and the market did not attract as much activity, either on the part of speculators or hedgers, as in the fall and early winter of 1959. Speculators, as in the previous surveys at the end of October, were buyers on balance in Maine potato futures, but speculative traders did not show such a heavy preference for the long side as in most previous years.

Single copies of the report, "Maine Potato Futures, October 28, 1960," may be obtained on request from the Commodity Exchange Authority, U. S. Department of Agriculture, Washington 25, D.C.

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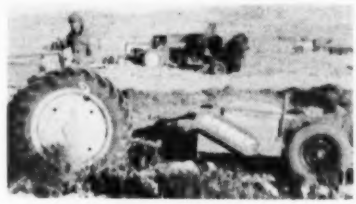

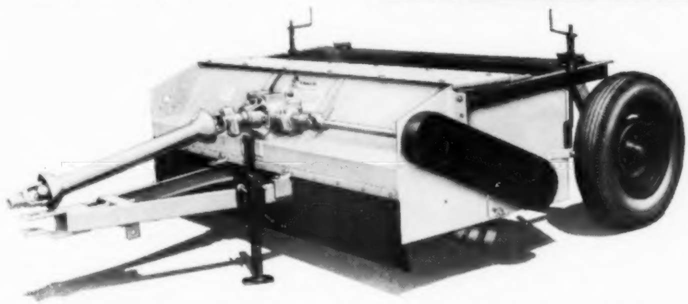

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ANNUAL MEETING

The Annual Meeting of THE POTATO ASSOCIATION OF AMERICA will be held in conjunction with HEPP, an organization of horticulturists, entomologists and plant pathologists from the Pacific Northwest. The meetings will be held at Wenatchee, Washington, July 25, 26, 27, 28.

A tour of the potato area will be conducted on July 25 and a tour of the fruit growing area on July 28. Papers will be presented on July 26 and 27.

Titles of papers to be presented at the meeting should be sent to Dr. Richard Sawyer, Secretary, Long Island Vegetable Research Station, Riverhead, L. I., N. Y., not later than June 10, 1961.

POTATO GROWERS 1961 YEARBOOK ACCLAIMED ONE OF THE NATION'S FINEST

First reviews of the 1961 Yearbook of the Potato Growers Association of California and Arizona, a reference book in potato marketing, production and utilization, have acclaimed it as one of the finest trade association publications dealing with a single commodity, in United States agriculture.

The 200-page publication, compiled and edited by potato marketing expert, Francis P. Pusateri, executive manager of the Association, deals with the numerous facets of potato economics, marketing, nutrition, production, research, transportation and utilization, and has been accomplished by close cooperation with national experts in these fields.

Outstanding multi-color inserts lend unusual quality and interest. This 17th edition, as expressed by experts, will again set new standards in the nation for trade association publications.

Past editions have been distributed to libraries, educational and banking institutions, local, state and federal governmental agencies, agricultural departments of many foreign countries, as well as to potato growers, shippers and receivers throughout the United States.

The Yearbook was released in connection with the Association's 17th Annual Convention on March 12, 13 and 14, at Bakersfield, California.

Copies may be purchased from the association's office, P. O. Box 83, Bakersfield, Calif.